THE STORY OF THE ELEMENTS

Argon

Ia	IIa	IIIb	IVb	Vb	VIb	VIIb	VIII			Ib	IIb	IIIa	IVa	Va	VIa	VIIa	0
1 H 1.0080																	2 He 4.003
3 Li 6.940	4 Be 9.013											5 B 10.82	6 C 12.011	7 N 14.008	8 O 16.000	9 F 19.00	10 Ne 20.183
11 Na 22.991	12 Mg 24.32											13 Al 26.98	14 Si 28.09	15 P 30.975	16 S 32.066	17 Cl 35.457	**18 Ar 39.944**
19 K 39.100	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.95	24 Cr 52.01	25 Mn 54.94	26 Fe 55.85	27 Co 58.94	28 Ni 58.71	29 Cu 63.54	30 Zn 65.38	31 Ga 69.72	32 Ge 72.60	33 As 74.92	34 Se 78.96	35 Br 79.916	36 Kr 83.80
37 Rb 85.48	38 Sr 87.63	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (99)	44 Ru 101.1	45 Rh 102.91	46 Pd 106.4	47 Ag 107.880	48 Cd 112.41	49 In 114.82	50 Sn 118.70	51 Sb 121.76	52 Te 127.61	53 I 126.91	54 Xe 131.30
55 Cs 132.91	56 Ba 137.36	57 La 138.92	72 Hf 178.50	73 Ta 180.95	74 W 183.86	75 Re 186.22	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 197.0	80 Hg 200.61	81 Tl 204.39	82 Pb 207.21	83 Bi 208.99	84 Po 210	85 At (210)	86 Rn 222
87 Fr (223)	88 Ra 226.05	89 Ac 227.0															

LANTHANUM SERIES	58 Ce 140.13	59 Pr 140.91	60 Nd 144.27	61 Pm (147)	62 Sm 150.35	63 Eu 152.0	64 Gd 157.26	65 Tb 158.93	66 Dy 162.51	67 Ho 164.94	68 Er 167.27	69 Tm 168.94	70 Yb 173.04	71 Lu 174.99
ACTINIUM SERIES	90 Th 232.05	91 Pa 231.	92 U 238.07	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (249)	98 Cf (251)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (253)	103 Lw (256)

March—April 1979

SARABHAI M CHEMICALS

THE STORY OF THE ELEMENTS

Argon

SARABHAI M CHEMICALS
BARODA

HISTORIC MILE-STONES

1785 HENRY CAVENDISH established the existence of some inert constituent in earth's atmosphere.

1868 Helium was discovered in the atmosphere of the sun.

1868 JANSEN and LOCKYEAR showed that solar prominences gave bright line spectra, which proved that there were immense volumes of gas composed of hydrogen and other elements.

1891 W. F. HILDEBRAND obtained an inert gas from uranite.

1894 LORD RAYLEIGH and SIR WILLIAM RAMSAY discovered Argon.

1895 RAMSAY obtained a gas from cleveite, while working for Argon.

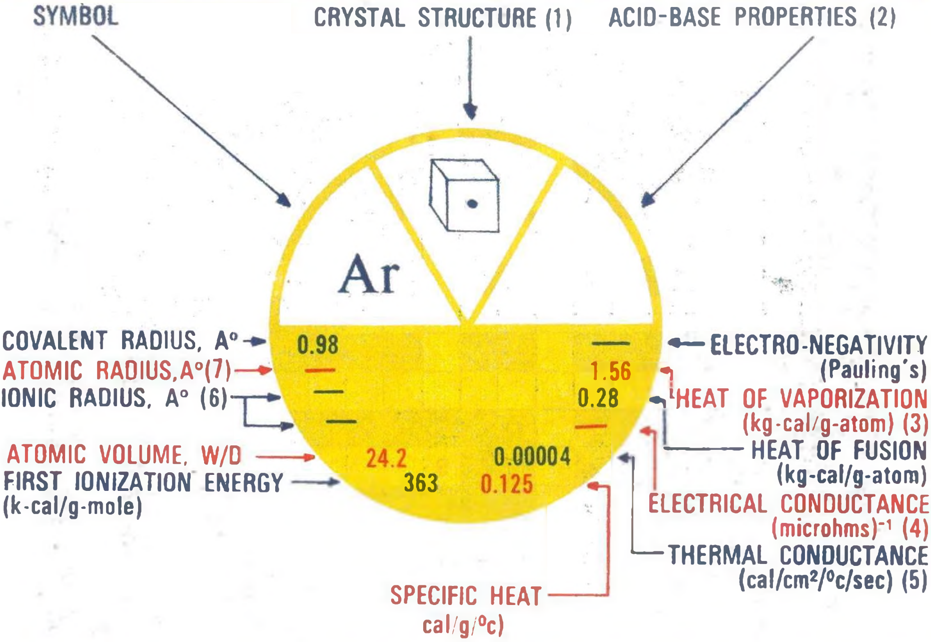
1898 RAMSAY discovered Neon.

1900 DORN discovered Radon.

1905 CADY and McFARLAND found a natural gas in Kansas, containing 2% helium.

1908 RAMSAY and W. GRAY isolated Radon as a gas given off by radium.

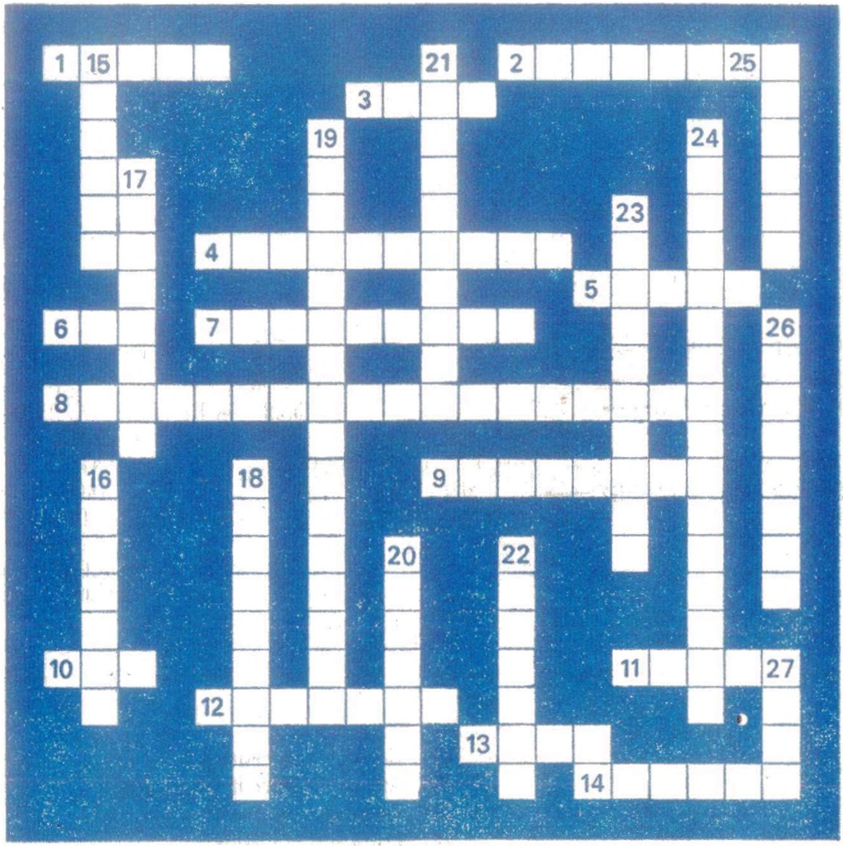
PERIODIC PROPERTIES OF ARGON



(1) Cubic, face centered
(2) Argon is inert in character.
(3) At boiling point.
(4) From 0°C to 20°C
(5) At room temperature
(6) Ionic (crystal) radii for co-ordination number 6
(7) Metallic radii for co-ordination number of 12

Sarabhai M Chemicals.

Chemistry Cross Word Puzzle : Argon

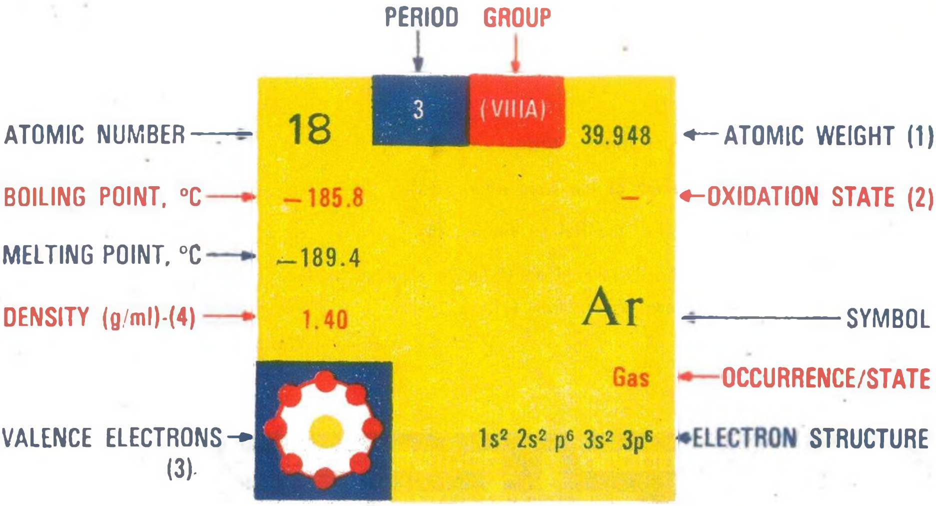


HORIZONTAL LEGEND

1. Most abundant of the *Rare Gases* or the Zero group of the Periodic System. (5).
2. One the two scientists who jointly announced on August 13, 1894, the discovery of argon. (8).
3. The *Group* of periodic table, the entire *Helium Family* belongs to. Write in words. (4).
4. The *colour* of the argon gas. (10).

(Continued on Page 6)

PHYSICAL PROPERTIES OF ARGON



PERIOD → 3

GROUP → (VIIIA)

ATOMIC NUMBER → 18

ATOMIC WEIGHT (1) → 39.948

BOILING POINT, °C → −185.8

OXIDATION STATE (2) → –

MELTING POINT, °C → −189.4

DENSITY (g/ml)-(4) → 1.40

SYMBOL → Ar

OCCURRENCE/STATE → Gas

VALENCE ELECTRONS (3)

ELECTRON STRUCTURE → $1s^2\ 2s^2\ p^6\ 3s^2\ 3p^6$

(1) Based upon Carbon-12.

(2) The element Argon has No Oxidation state. Argon is chemically inert.

(3) Argon has 8 valence electrons in its outer most orbit.

(4) Value for liquid at the boiling point.

Sarabhai M Chemicals.

(Continued from Page 4)

5. The *principal* and the *common* property of all the zero group element (5).

6. The *english* meaning of the word *helium*. (3).

7. The scientist who determined very definite existence for the existence of *some inert* constituent in the earth's atmosphere. (9).

8. The lighting *medium* wherein argon was used in large-scale in olden time. (8 + 5 + 5).

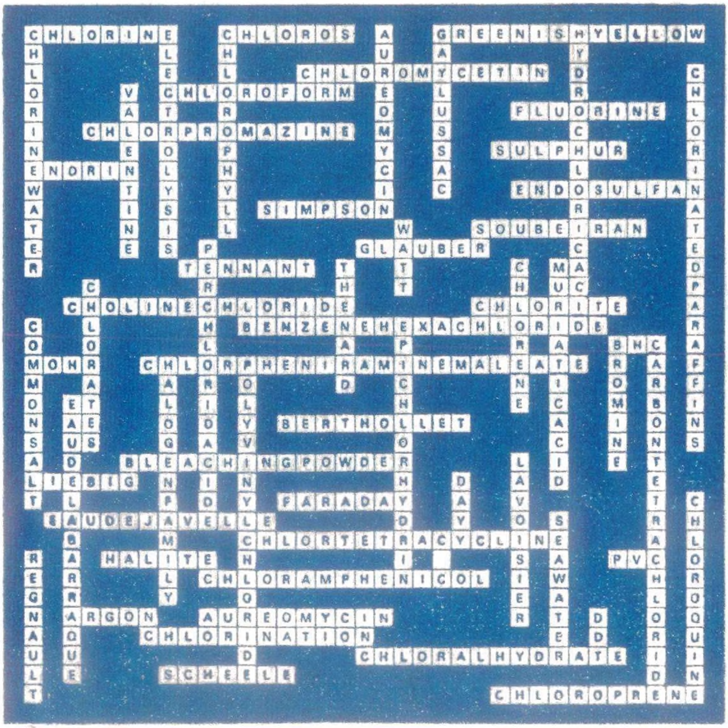
9. *Atomic number* of argon. Write in words. (8).

10. The english meaning of the word *neon*. (3).

11. The *fifth* member of the Helium Family. (5).

12. The scientist who discovered an unknown element in the Sun's spectrum, which was later on known as *Helium*. (7).

(Continued on Page 22)



CHLORINE

Solution to the Chemistry Cross Word Puzzle C H L O R I N E 'The Story of Elements' "CHLORINE" (Part One).

ARGON

Chemical element number 18, Argon, Ar, is the third member of the family of elements constituting group 0 (zero) of the Periodic Table. Group 0 is also known as *"Helium Family", "Noble Gases", "Rare Gases",* or *"Inert Gases".* Although argon is placed in the "Rare Gases" group, it is not rare.

Argon is a chemical element which is colourless, odourless, and tasteless. Argon is the most abundant of the family of inert gases, accounting for about 1% of the earth's atmosphere, and is commercially the most important. It is also found in traces in minerals and meteorites.

Argon is obtained from liquid air by the fractionation process and has a variety of applications, usually based on its inertness.

DISCOVERY

Argon was discovered by the 3rd Baron Rayleigh and Sir William Ramsay in 1894 and was the first of the inert gases to be isolated from a terrestrial sources. (Helium, q.v., was discovered in the atmosphere of the sun in 1868.). Very definite evidence for the existence of some inert constitutent in the earth's atmosphere was, however, obtained by Henry Cavendish as early as 1785. Cavendish designed experiments to test whether the nitrogen of the atmosphere ("phlogisticated air") was really homogeneous or whether it might perhaps be a mixture of different substances. In these experiments a mixture of air and oxygen was sparked over potash, which absorbed the oxides of nitrogen formed. After removing the excess oxygen, a small bubble of gas remained, which could not be diminished by further sparking with oxygen. It is now known that the residue must have consisted mainly of argon, but Cavendish did not pursue the experiments further. He concluded "that if there is any part of the phlogisticated air (nitrogen) of our atmosphere which differs from the rest, and cannot be reduced to nitrous acid, we may safely conclude, that it is not more than $\frac{1}{200}$ part of the whole".

This evidence is overlooked for more than a century, until Lord Rayleigh, in the course of a series of accurate redeterminations, of the densities of the principal gases, found that the density of atmospheric nitrogen was always about 0.5% greater than that of nitrogen derived from chemical sources; e.g., from ammonia or nitrous oxide (Proc. Roy. Soc., 1894). This result very clearly pointed to the presence of some hitherto unknown gas and brought to light the earlier work of Cavendish. The gas responsible, called argon (from the Greek argon, derived from argos, "idle") because of its chemical inertness, was finally isolated by Ramsay and Rayleigh (Proc. Roy. Soc., 1895), who employed a method similar to that of Cavendish. They also obtained the gas by passing air over heated copper, to remove the oxygen, and then over heated magnesium, which removes the nitrogen as nitride. The argon carefully purified in this way, was found to constitute nearly 1% by volume of the atmosphere. It has had a density of approximately 20, relative to hydrogen as 1. Ramsay and Rayleigh also showed by measurement of the ratio of the specific heats at constant pressure and constant volume, that the energy absorbed on heating is wholly translatory and that the gas must therefore be monatomic. The atomic weight is thus the same as the molecular weight, which the density measurement shows to be approximately equal to 40.

OCCURRENCE AND ORIGIN

Argon constitutes 0.934% by volume of the earth's atmosphere. Of this argon 99.6% is the argon-40 isotope; the remainder is argon-36 (0.337%) and argon-38 (0.063%). There is good evidence that all the argon-40 in the air came from the radioactive decomposition of potassium-40.

It is estimated that about 0.0004% by weight of the earth's crust is argon. Argon also occurs outside the earth; the best estimate is that there are about 15 atoms of argon per 100 atoms of silicon in the visible universe.

Argon was discovered by Sir William Ramsay in 1894 as the result of Lord Rayleigh's observation that samples of nitrogen prepared from ammonia were always lighter than "nitrogen" prepared by absorbing the oxygen, carbon dioxide, and moisture from air. Ramsay prepared argon by passing this atmospheric "nitrogen" over hot magnesium until no more gas was absorbed. Then inert remainder was identified as a new element by the previously unobserved lines in its spectrum.

PHYSICAL AND CHEMICAL PROPERTIES

Argon is colorless, odorless, and tasteless. It is a gas under ordinary conditions, but can readily be liquefied. Properties of argon are listed in the table.

Properties of argon

Atomic number	18
Atomic weight	39.944
Melting point, °C	−189.4
Boiling point at 1 atm pressure, °C	−185.9
Gas density at 0 °C and 1 atm pressure, g/liter	1.7839
Liquid density at its boiling point, g/ml	1.402
Solubility in water, ml gas per 1000 g water at 25 °C and 1 atm pressure.	33.6

Argon does not form any chemical compounds in the ordinary sense of the word although it does form some weakly bonded clathrate compounds with water, hydroquinone, and phenol. There is only one atom in each molecule of argon.

Argon is monatomic. The 18 electrons are arranged in shells, 2, 8, 8, the outermost shell being a complete octet, which gives the atom zero valence and complete chemical inertness. It is known to exist in three naturally occurring isotopic forms, of mass number 40, 38 and 36, the relative abundances being 99.60%, 0.06% and 0.34%. The atomic weight is thereofore just a little below 40.

Argon condenses to a colourless liquid at –185.8°C and to a crystalline solid at –189.3°. The crystal structure indicates a face-centred cubic lattice with *a* (cube edge) = 5.42 Å (angstrom units = 10^{-8} cm), the contact distance between the argon atoms being 3.83 Å. The density of the liquid at –183° is 1.374. The critical temperature is –122.4°, the critical pressure 48 atm and the critical density is 0.509. The solubility of the gas in water is considerable, 3.94 vol dissolving in 100 vol of water at 12°, this being more than double the solubility of nitrogen. The spectrum of argon is not outstanding and consists of many line spread over the whole vissual range. At low pressure the discharge is pale red in colour, changing to a steely blue when a condensed discharge is used.

In spite of many attempts, no compounds involving normal valency bonds between argon and the atoms of other elements had been prepared by the 1950s, although several complexes, of varying degrees of stabiiity, had been recorded. At a pressure of 150 atm and in the presence of ice, a hydrate of composition $A,5.5H_2O$ is recorded, which is extremely unstable with a dissociation pressure of nearly 100 atm. Freezing-point data for the system boron tri-fluoride–argon indicate the formation of a series of unstable complexes of composition Ar, BF_3; $Ar, 2BF_3$; $Ar,_3 BF_2$; $Ar,6BF_3$; $Ar, 8BF_3$; and $Ar,16BF_3$. The most interesting and the best established "compound" containing argon is a quinol clathrate of composition $3C_6H_4(OH)_20.8A$ prepared by H. M. Powell *(J. Chem. Soc.,* 1950). The structure of this type of complex, fully established by X–ray analysis, consists of a cagelike arrangement of quinol molecules held together by hydrogen bonds. A cavity about 4 Å in diameter is formed between every three quinol molecules, and in these cavities various small molecules or large atoms can be trapped when the substance crystallizes. The argon compound is prepared by exposing a solution of quinol to argon at a pressure of about 40 atm. When the compound crystallizes out it is quite stable and contains almost the theoretical quantity of one argon atom to every three quinol molecules. On solution, however, the argon escapes with vigorous effervescence. The argon is clearly not bonded to any of the other atoms but is trapped in a cavity formed between the other molecules. A similar type of explanation probably applies in the case of some other complexes that have been described.

MANUFACTURE

The methods described under *Discovery,* although laborious, may be used to produce small quantities of argon. A mixture of pure dry lime and magnesium powder may also be used. When this mixture is heated to redness, metallic calcium is formed, which reacts with nitrogen to give the nitride, Ca_3N_2.

For larger-scale production, the removal of both nitrogen and oxygen in one operation by passing air slowly over heated calcium carbide is a more suitable process. In this reaction carbon dioxide (which is easily removed) and calcium cyanamide, a solid, $CaCN_2$, are formed. This cyanamide process was used in America for the first commercial production of argon in quantity in 1914.

None of the above methods is capable of separating argon from the other inert gases, helium, neon, krypton and xenon (qq. v.), which are also present in very small amounts in the atmosphere (q. v.). This separation can, however, be effected by the careful fractionation of liquid air, the process now exclusively used in the large-scale industrial production of argon.

The helium-group elements are all commercially produced by cryogenic separation methods. Helium-4 is produced primarily by separation from helium-bearing natural gases. Neon, argon, krypton, and xenon, as well as very small quantities of helium, are obtained by separation from air. Radon is separated from the gases evolved by radium. Helium-3 is obtained by separation from its parent element tritium.

Industrially, oxygen and nitrogen are produced by the large-scale cryogenic distillation of liquefied air but air also contains nearly 1% argon and lessser amounts of neon, helium, krypton, xenon. The concentrations of helium-group elements in the atmosphere are listed in Table 2. Argon, neon, krypton, xenon are produced commercially mainly as by products from large oxygen and nitrogen plants, since air is the only practical source of these materials.

Table 2 – Abundances of the Helium-Group Elements in the Earth's Crust and Atmosphere.

Element	Earth's crust, a* ppm by wt	Atmosphere (dry air) ppm by vol
helium	8×10^{-3}	5.24
neon	5×10^{-3}	18.18
argon	3.5	9340
krypton	1.9×10^{-4}	1.14
xenon	2.9×10^{-5}	8.6×10^{-2}
radon	4×10^{-13}	6×10^{-14} b†

*a Includes oceans and atmosphere.

†b Average value. The concentration may vary from one location to another.

The boiling point of liquid argon, −185.7°C, is intermediate between that of nitrogen (−196°) and oxygen (−183°). Helium and neon have much lower boiling point and can therefore be isolated from the more volatile fraction, while the higher boiling points of krypton and xenon ensure that they are retained in the less volatile fractions. But the argon is closely associated with the oxygen and nitrogen fractions, and these three gases together comprise more than 99.99% of the total. A rectification column consisting of a number of plates, with taps at different levels, is employed. The argon accumulates on the lower plates of the column, and at a certain point gas containing about 10% argon mixed mainly with oxygen, can be withdrawn. This gas must then be redistilled or rectified, in a separate column, and finally the remaining oxygen can be easily removed by combustion. The gas obtained in this way is reasonably pure, although traces of the other rare gases still remain. These do not interfere with its main use, in the electric lamp industry; but if chemically pure argon is required, further processes of fractional condensation and evaporation and also fractional adsorption over charcoal may be employed.

DISTRIBUTION

Because argon constitutes almost 1% of the air, it is plentiful and cheap. It is sold as a gas under pressure in steel cylinders, and as a liquid in insulated tanks ranging in size from a capacity of about 3oo lb of argon in a vessel weighing about 550 lb when full that can be handled by one man, to large tanks mounted on truck trailers, and railroad tank cars; each holding about 90,000 lb of argon.

ANALYTICAL DETERMINATION

The principal modern methods of detecting and quantitively determining of the argon content in gases are mass spectrometry and gas chromatography. Until these methods were developed, it was necessary to separate argon from other inert gases by selective low-temperature adsorption on activated carbon in order to determine how much argon was present in a mixture. The older method of detecting argon is by its characteristic emmission spectrum, obtained by passing a gas sample through an electric discharge tube at low pressure and analysing the emitted light with a spectrometer.

APPLICATIONS

The oldest large-scale use for argon is in filling electric light bulbs, but in recent years the two uses which have consumed the most argon are argon-shielded arc welding and the blanketing of metallurgical operations in which metals such as titanium, that react with components of the air, are involved.

Argon and argon-krypton mixtures are used, along with a little mercury vapor, to fill fluorescent lamps. The rare gases make the lamps easier to start.

Argon mixed with a little neon is used to fill luminous electric-discharge tubes employed in advertising signs (similar to neon signs) when a blue or green colour is desired instead of the red colour of neon.

Argon is also used in filling gas-filled thyratrons, Geiger-Muller radiation counters, ionization chambers which measure cosmic radiation, and electron tubes of various kinds. Argon is used as a substitute for helium in mass spectrometer-type leak detectors. In the laboratory, argon is frequently used as the mobile phase in gas chromatography and as the atmosphere in inert-atmosphere dry-boxes in which manipulation of very reactive chemicals is carried out.

The largest single use of argon is in inert-gas-shielded arc welding. In ordinary metal arc welding, a flux is used to prevent the hot metal from reacting with constituents for the air. In inert-gas-shielded arc welding, a gas such as argon, helium or mixtures of the two is substituted for the flux. The inert gas flows through the arc and over the welding area. Gas-shielded arc welding has proved highly successful for stainless steel, aluminium, magnesium, titanium, copper alloys, and nickel alloys.

A use which has become increasingly important in recent years is to furnish a protective atmosphere for the metallurgy of reactive elements. This is Important for example, in the case of titanium, which when hot can be handled only in a vacuum or in an inert gas atmosphere, since it reacts readily with oxygen, nitrogen, and moisture. Argon is used to provide an inert atmosphere while titanium is being produced from titanium chloride, and later when the sponge that is first produced is melted, or when titanium, is rolled to give titanium sheet and structural members.

Argon is also used to provide an inert atmosphere for the growth of silicon and germanium crystals for use in transistors. Helium has been used to some extent for these purposes, but is being displaced to a considerable extent by the far more abundant and available argon.

One of the newest applications of argon is in the electric arc cutting of nonferrous metals such as aluminium. For many years, steel has been cut by oxygen cutting torches, but these torches were ineffective with aluminium because of the aluminium oxide film that forms whenever aluminium is exposed to oxygen, and because aluminium is such a good conductor of heat that the heat of an ordinary torch cannot be concentrated sufficiently to make a clean cut. The problem of cutting metals such as aluminium has been solved by the use of an electric arc torch in which a mixture of argon and hydrogen is forced through a constricted arc. The constriction intensifies the arc and forces the gas to flow through at high velocity. The argon ionizes readily and helps to maintain the arc. The hydrogen molecules are dissociated to hydrogen atoms in the arc. These atoms recombine on the surface of the aluminium with evolution of large quantities of heat, thus melting the aluminium. The hydrogen prevents oxidation of the molten aluminium, which flows easily out of the kerf. Clean cuts can readily be made in 1/4-in. aluminium plate with this process at speeds up to 600 in./min; much thicker aluminium plate can also be cut by the argon-hydrogen arc torch.

The Review of Argon would remain incomplete without a passing reference to all the elements of that group. In view of this a separate chapter under caption : "ELEMENTS OF GROUP O" has been devoted to the general discussion of all the Group O elements, namely, Helium, Neon, Argon, Krypton, Xenon and Radon.

Elements of Group O

This group, *the inert elements,* consists of helium, neon, argon, krypton, xenon, and radon. These elements are also known as members of the Helium Family. Each is characterized by the important structural feature that the outermost atomic orbit of electrons is completely filled, thus nullifying any propensity for reaction in order to achieve chemical inerteness. Under unusual reaction conditions, there is some evidence that these inert elements may be caused to form hydrates and unite with hydrogen and various metals. In general, such "compounds" are quite unstable under ambient conditions. To the contrary, some relatively stable fluorides; eg, XeF_2, XeF_4, and XeF_6, are known. However, in comparison with other elements, those of Group Zero are still logically and usefully classed as chemically inert. In contrast with hydrogen, oxygen, and other diatomic gases, the molecules of inert elements in the gaseous state are monatomic.

Physically, all elements of Group Zero are colourless, odourless gases under ordinary conditions of temperature and pressure. They vary widely in atomic mass and atomic volume, and these differences are reflected in the values of their physical constants.

At the time Mendeleeff constructed his original periodic table, the inert elements were unknown and thus no spaces were provided for them. With their later discovery, however, it became apparent both from the standpoints of atomic structure and properties that these elements fitted nicely into Mendeleeff's arrangement and explained the transition in properties from decidedly electronegative elements such as the halogens to pronounced electropositive elements such as the alkali metals.

Table I — Some Characteristics of Group O Elements

Symbol	He	Ne	Ar	Kr	Xe	Rn
Atomic number	2	10	18	36	54	86
Atomic weight	4.0026	20.183	39.948	83.80	131.30	(222)[a]
Density (Gm/L at 0°C and 1 atmos)	0.178	0.900	1.78	3.71	5.85	9.73
Melting point (°K)	0.9	24	84	104	133	202
Boiling point (°K)	4.2	27	87	121	164	211
Critical temperature (°K)	5.2	44	151	120	290	378
Critical Pressure (atmos)	2.3	27	48	54	58	62
% by volume in air	5×10^{-4}	15×10^{-4}	0.94	11×10^{-5}	9×10^{-6}	

[a] Mass number of the isotope of longest known half-life.

HISTORY

In the course of investigations on the density of nitrogen, Lord Rayleigh noted a consistent difference in the density of atmospheric nitrogen and chemical nitrogen from ammonia, nitric oxide, nitrous oxide, and ammonium nitrate. Atmospheric nitrogen was about 0.5 % higher in density.

Stimulated by Lord Rayleigh's work, W. Ramsay treated a sample of atmospheric nitrogen with hot magnesium and isolated a 100 ml sample that did not react. This gas had a relative density of 19.075 (O =16) and amounted to about 1 % of the original volume of nitrogen. Lord Rayleigh and Ramsay announced jointly on August 13, 1894, the discovery of argon (Greek *argos,* inactive), which had been anticipated over a century earlier by Cavendish who obtained an inert residue when an electric discharge was passed through air and oxygen.

In 1868 Janseen, Lockyer, and others showed that solar prominences gave bright line spectra, which proved that they were immense volumes of gas composed of hydrogen and other elements. Lockyer noticed a line in the yellow part of the spectrum slightly closer to the green than D lines of sodium. He thought this line was due to an unknown element in the sun, which he named helium (Greek *helios,* the sun). In 1891 W. F. Hildebrand obtained an inert gas from uranite which gave spectral lines that did not coincide with the mapped ones of that time. In 1895 Ramsay learned of Hildebrand's work and, as he was searching for argon, extracted a gas from cleveite. In addition to lines of argon he saw the prominent yellow line that Lockyer had found in the solar chromosphere. In 1905 Cady and McFarland found that natural gas from a well near Dexter, Kansas, contained nearly 2% helium.

Ramsay publicly predicted the existence of neon (Greek *neos,* new). He privately predicted the existence of Krypton (Greek *Kryptos,* hidden) and Xenon (Greek *Xenos,* strange). In 1898, Ramsay discovered neon as the volatile fraction from a sample of argon condensed with liquid air refrigerant. A month later Ramsay isolated xenon from the residue that resulted from the evaporation of liquid air.

Radon was discovered by Dorn in 1900 and isolated by Ramsay and W. Gray in 1908 as a gas given off by radium.

OCCURRENCE

The helium group gases are widely distributed through out the universe. Helium is a major constituent of most stars, and is believed to be formed and consumed in thermonuclear reactions at temperatures from 5 million to 5 billion degrees. Under these conditions hydrogen can react to form helium. At sufficiently high temperatures carbon and oxygen may react with helium to form neon. At the very highest temperatures other nuclear reactions yield the heavy elements, including krypton and xenon.

Many stars go through a phase in which their rate of energy production and temperature increases to the point where the stars explode. These stars become *nova* or *supernova.* These cataclysms eject enormous quantities of gas into space and partially account for the existence of the helium-group elements in interstellar gas clouds. Some of the matter in these clouds may have also originated at the beginning of the universe and never condensed into a stellar body.

It is likely that neon, krypton xenon, and most of the argon isotopes (except ^{40}Ar) were originally part of the mass of matter that condensed to form the earth.

The principal isotope of argon (^{40}Ar) probably was formed by the radioactive decay of potassium-40 (^{40}K) in the earth's crust. The argon so formed gradually escaped to the atmosphere. Radon is formed by the radioactive decay of radium in the earth and, like argon, escapes to the atmosphere.

The earth's gravitational field is not large enough to prevent helium's escaping from the earth. Thus, it is likely that any helium on earth today was produced since the earth was formed and solidified. Any helium present in the original gas cloud would have long since escaped. In the atmosphere a steady state has been reached between the gain of helium from the earth and the loss of helium by escape into space. Because of the constant mixing of gases in the atmosphere, the composition of the atmosphere, upto a height of sixty miles, is constant with respect to all the helium-group gases except radon.

Naturally occurring krypton is nonradioactive. However, with the advent of the operation of nuclear reactors and nuclear weapon testing, the radioactive isotope krypton-85 is now found in the atmosphere.

Argon and helium are the most abundant helium-group elements on earth. The predominance of argon and helium on earth is because of their being continuously formed from more abundant elements which were condensed when the earth was formed.

The atmosphere is the commercial source of neon, argon, krypton and xenon. However, the principal source of helium in the United States is from certain natural gas wells in which the natural gas may contain up to 8% helium.

The United States posses the largest reserve of helium-bearing natural gas in the Western World. However, helium-bearing natural gas has been discovered at Swift Current, Saskatchewan, Canada.

PHYSICAL PROPERTIES

All of the helium-group elements are gases at room temperature and pressure. They are colourless, odourless and tasteless. Chemically, they are nearly inert. While a few stable chemical compounds have been prepared from radon, xenon, and krypton, none have been reported for helium, neon, and argon. The helium-group elements are monatomic. These monatomic molecules are considered to have perfect spherical symmetry. Because of this molecular simplicity, there is much theoretical interest in the physical properties of the helium group elements. With the exception of radon, the physical properties of helium group elements have been relatively completely determined experimentally.

Radon is the heaviest member of the helium-group elements and of the normally gaseous elements.

The physical properties of argon, krypton, and xenon are quite normal. In fact, they are frequently selected as standard substances to which the properties of less normal substances are compared in order to empirically estimate the effects on physical properties of such things as permanent molecular dipole moments, nonspherical molecular shapes, etc.

APPLICATIONS

Helium owes its pharmacological actions exclusively to its physical properties. A mixture of 80 parts Helium and 20 parts oxygen is only one-third as heavy as air. Such mixtures are used in the treatment of respiratory obstruction, and are of great value in relieving status asthmaticus and the symptoms arising from inflammatory obstructions. When administered in asphyxia, the light mixture penetrates the air passages more readily than mixtures of nitrogen and oxygen.

Helium mixed with oxygen is supplied to workers in tunnels and to deep sea diverse as a substitute for ordinary air. Helium is preferable to nitrogen for this purpose. It is less soluble in the blood and is therefore less likely to cause the "bends"; also, less time is required for compression and decompression. Helium is employed in filling balloons and dirigibles; it has less lifting power than hydrogen but possesses the extremely important advantage of being nonflammable. It is also used in a variety of applications involving very low temperatures and in applications requiring an inert atmosphere.

The primary use of neon is in the familier neon advertising signs. The characteristic orange-red glow results when an electric discharge passes through the gas under reduced pressure. The colour may be modified by the presence of orher gases or by use of tubes of coloured glass.

Argon, because of its relative abundance in air, can be produced relatively cheaply. It therefore finds rather extensive use, particularly in the electric lighting industry. In the ordinary electric lamp bulb, it is superior to nitrogen primarily because of the retarding effect it exerts on evaporation of the metallic filament. Fluorescent light tubes contain argon and mercury vapor under low pressure.

Krypton and xenon have been investigated for possible use as anesthetics and for use in photography. However, the sparsity with which these elements occur in nature imposses severe limitations on their use.

Radon has been used instead of radium in the treatment of certain types of cancer. Sealed tubes containing the element are imbedded in the tissues to be treated. Both radium and radon emit alpha particles in the first stage of their radioactive decay.

Chemistry Cross Word Puzzle : Argon

(Continued from Page 6)

13. The scientist who discovered the element *Radon*. (4).

14. The english meaning of the greek word *Krypton*. (6).

VERTICAL LEGEND

15. One of the two scientists who isolated *neon* in 1898 (6).

16. One of two scientists who coined the name : *Helium* to an unknown element discovered by Janssen. (7)

17. The english meaning for the word *Xenon.* (8)

18. The scientist who, alongwith Lockyer, coined the word : *Helium* to an unknown element discovered by Janssen in the Sun's spectrum. (9).

19. Argon, and argon-krypton mixtures are used alongwith a little mercury vapour, to fill *special kind of lamps*. Name these lamps. (11 + 5)

20. Sir William Ramsay, alongwith an another scientist isolated *neon*. Name this second scientist. (7).

21. The *largest single use* of argon is in a specific type of inert-gas-shield welding. Name it. (3 + 7).

22. One of the two vertical neighbours of argon. (7).

23. The *pioneer* of the Periodic Table of Elements. (10).

24. Argon mixed with a little neon is used to fill *luminous* electric-discharge tubes, similar to neon-signs, employed as an advertising media. (11 + 5)

25. *First* member of the Helium Family and the Group Zero. Its mixture with Oxygen (80:20) is used in the treatment of *Respiratory Asthmaticus.* (6).

26. The only *horizontal* neighbour of argon. (8).

27. An *inert* gas of group Zero. Its primary use is in the familar advertising signs. (4).

BIBLIOGRAPHY

1. Moeller, T., *Inorganic Chemistry, An Advanced Treatise*, Wiley, New York, 1952.

2. Kimball, A. H., *Bibliography of Research on Heavy Hydrogen Compounds*, McGraw. Hill, New York, 1949.

3. *Chem. Eng. News.* 41, No. 5,36 (1963).

4. *Encyclopedia Britannica*, 2, 332 (1962), Encyclopedia Britannica Ltd. London.

5. Thorpe J. F.; Whiteley, M. A.; *Thorpe's Dictionary of Applied Chemistry*, 4th ed., Vol. 1 (1937).

6. Gross, F. P.; Jr; *Rare gases in everyday use, J Chem. Educ*, 18 (11) : 533–539, (1941).

7. Jones, R. A.; Dubs, M. A.; *Helium-Group Gases* in R. E. Kirk and D. F. Othmer (eds.), *Encyclopedia of Chemical Technology*, vol. 10, page 862–888 (1966).

8. On the argon front, *Chem Week*, 75 (16); 93–95, (1954).

9. Hoover, J. E.; *Remington's Pharmaceutical Sciences*, 13th ed., p. 706–767 (1965).

10. Travers, M. W.; *Discovery of the Rare Gases*, Edward Arnold Co., London, (1928).

11. Lovejoy, D. R.; *Nature*, 197, 353–354 (1963).

12. *McGraw-Hill Encyclopedia of Science & Technology*; 1, 530–531 (1960).

13. *Chambers' Encyclopedia*; 1, George Newnes Ltd., London (1959).

14. Young, L. E.; Petty, W. M.; *Chemistry for Progress*: Prentice-Hall Inc., Englewood Cliffs; (1957).

15. Ames, M. U.; Baker, A. O.; Leaky, J. F.; *Science for your Needs*: Prentice-Hall Inc., Englewood Cliffs; (1956).

16. Vlasov, L.; Trifonov, D; *107 Stories about Chemistry;* Mir Publishers, Moscow, (1970).

17. Sienko, M. J.; Plane, R. A.; *Chemistry;* Second Edition; McGraw-Hill Book Co. Inc., New York and Kogakusha Co. Ltd., Tokyo (1961).

18. Parr, J. A.; Young, R. A.; *Parr's Concise Medical Encyclopedia;* Elsevier Publishing Co. Ltd., Amsterdam (1965).

19. Newman, J. R.; *The Harper Encyclopedia of Science,* 1, Harper & Row Publications (1963).

CONCLUDED

Published by H. H. Kavarana on behalf of the Proprietors Sarabhai M Chemicals from Gorwa Road, Baroda and Printed by Paper & Allied Products, GIDC, Industrial Estate Makarpura, Baroda.
VIII 06'79/10,000

SARABHAI M CHEMICALS

HEAD OFFICE & FACTORY :
Post Box No : 80, Baroda, 390001.
Gorwa Road, Baroda-390007 Gram : SAMCHEM.

REGIONAL OFFICES AND DEPOTS :

BOMBAY :
A-Z Industrial Estate, Fergusson Road P. B. No : 16319.
Bombay-400013 Gram : CHEMSAM.

CALCUTTA :
C. I. T. Road, Scheme LII, Entally (2/1/4 Deb Lane) P. B. No : 11209
Calcutta-700014 Gram : CHEMSAM.

MADRAS :
123, Angappa Naicken Street, P. B. No : 1271
Madras-600001 Gram : CHEMSAM.

DELHI :
2E/25, Jhandewalan Extension, 1st Floor.
Delhi-110055.